The Morphology and Biology of a Canadian Cattle-Infesting Black Fly,

Simulium simile Mall. (Diptera, Simuliidae)

By A. E. CAMERON, M.A., D.Sc., F.E.S.,
Entomologist-in-charge for Saskatchewan

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The Morphology and Biology of a Canadian Cattle-infesting Black Fly, *Simulium simile* Mal. (Diptera, Simuliidae)

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Introduction

The subject-matter of this paper was drafted during the time that the author was associated with the Dominion Entomological Branch, in the capacity of Entomologist-in-charge for the province of Saskatchewan. The work involved in the completion of the manuscript, has been carried on intermittently, according as other duties allowed, since the time of arrival of the author in Saskatchewan in July, 1917. Some preliminary observations were made on *Simulium simile* in the summer of 1917.* These have now been supplemented by further study. At the time that the species was first encountered by the author, it was as yet undescribed, and an inquiry concerning its identity addressed to J. R. Malloch, of the Illinois State Laboratory of Natural History, Urbana, Illinois, elicited the information in April, 1918, that this particular species was identical with *S. simile*, which he had recently described from material submitted to him by the Canadian Arctic Expedition, 1913-18. This description† was published in the following year from specimens collected by R. M. Anderson at Hood river, Arctic sound, Northwest Territories, August 28, 1915, and from Bathurst inlet, Northwest Territories, September 1, 1915. According to Malloch the species is closely related to *S. arcticum*, but differs from the latter chiefly in the different coloration of the legs and the absence of long, erect, dark hairs on the dorsal surface of the thorax.‡

Only the female was available to Malloch. I am able to state definitely that none of the three pupæ collected by F. Johansen at Bernard harbour, Dolphin and Union strait, Northwest Territories, on August 16, 1915, July 10, 1916 and August 16, 1915, and described by Malloch on page 43 of the above-mentioned report as *Simulium*, sp. 2, *Simulium*, sp. 3, and *Simulium*, sp. 4 respectively, belong to *S. simile*.

As a result of this investigation I am now able to associate *S. simile* with its larva and pupa, hitherto unknown, and I am presenting descriptions of these two stages with explanatory illustrations, as well as descriptions of the female and male, of which the latter sex has not been previously identified. The descriptions have been made from material reared in specially constructed breeding-tanks of galvanized iron, in which an intake-pipe at one end was attached to a laboratory water-tap, and an outflow-pipe at the other was led away to a sink. A continuous stream of water passed through the tanks, and each tank was so adjusted that the incoming stream passed downward over the surface of a smooth glass plate extending the whole breadth of the inside of the tank, sloping at an angle of 45 degrees and supported by flanges on either side. From the glass plate, the lower edge of which did not reach to the bottom of the tank, the water passed downwards over a small, sloping mound of stones, which rested on the floor of the tank. The latter was covered with river mud. By a careful adjustment of the faucet, the required current was obtained, and, although many larvæ were carried away in the outflow from time to time, large numbers were successfully reared through the pupa to the adult stage. The top of the

* Cameron, A. E.—"Some Blood-Sucking Flies of Saskatchewan"—Agric. Gaz. Canada, vol. V, No. 6, 1918, pp. 556-561.

† Malloch, J. R. *et alii*.—"Report of the Canadian Arctic Expedition" 1913-1918, vol. III, pt. C, pp. 42, 43.

‡ Malloch, J. R.—"American Black-Flies or Buffalo Gnats." U.S. Dept. Agric., Bur. of Ent., Tech. Series 26, 1914, p. 37.

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tank was closed by a tight-fitting glass cover, which was darkened by an overlying fabric impenetrable to light, and, as the flies emerged, they escaped from the tank into two large glass vials fitted tightly into apertures on one side of the tank, well above the water-level, where they could be easily removed. The water passing rapidly over the glass plate inside the tank, dashed against the stones below with some force. Thus the water was kept well oxygenated, and the conditions of the natural habitat were very closely approximated as regards its most salient characteristics.

The territory covered during the progress of the investigation included that portion of the valley of the South Saskatchewan river extending in a more or less straight course from 10 miles south of the city of Saskatoon to Prince Albert, about 90 miles northeast of Saskatoon, and also the North Saskatchewan river in the vicinity of Prince Albert. The two rivers become confluent about 30 miles east of Prince Albert as the Saskatchewan river, which empties into Cedar lake in Northern Manitoba. The laboratory work was carried on at the University of Saskatchewan, and the material required for the breeding of the species was obtained in unlimited quantity from the river at Saskatoon, about half-a-mile from the university (fig. 8, A and B). An opportunity was also taken of making some tentative observations on species of *Simulium* other than *S. simile* occurring in the above-mentioned territory, including *Simulium bracteatum* Coq. (*Simulium aureum* Fries), *Simulium venustum* Say, *Simulium vittatum* Zett., and *Simulium* sp. undet., which is considered by Mr. Malloch to be close to *Simulium bivittatum* Mall. The early stages of these species with the exception of the last, which probably breeds in the Saskatchewan river, were found in a small stream that drains into the South Saskatchewan river, five miles north of Saskatoon. The larvæ and pupæ of both *S. vittatum* and *S. venustum* have been collected in the Souris river at Oxbow (10. VI. 20) in southeastern Saskatchewan, and also in the bed of a small stream at Maple creek (7. VI. 21) in the southwest part of the province.

Description

Egg (fig. 1, B).—Length 0.33 mm., breadth 0.24 mm. Colour pale yellowish-white. General shape triangular with angles rounded. The shell is thin but apparently tough and is seen to be transparent when egg is ruptured.

The eggs are not laid singly but in large cake-like masses, embedded in a soft, elastic, gelatinous matrix, by means of which they adhere readily to the surfaces of the stones on which they are deposited. These masses consist of thousands of eggs in a single layer, which are aparently the product of a large number of females, that select the same spot for oviposition. The adhesive properties of the matrix prevents their being washed away from the surface of their attachment, which is at, or close to, the water-line, where the spray, dashing over the stones, keeps them in a moistened condition. The matrix retains its elasticity indefinitely in seventy per cent alcohol, but becomes hardened in ninety per cent and absolute.

Female (fig. 1A).—Length 3-4 mm. General appearance gray. *Head* black with frons, clypeus, vertex and genæ bedusted with a silvery-white pollinosity, which is thickest on the clypeus; sides of frons sub-parallel approaching each other slightly beneath, then spreading out above the bases of the antennæ, where the frons extends about one-third across the breadth of the head indenting the inner margins of the eyes; dorsally, the frons expands slightly at its confluence with the vertex; surface of the clypeus stands out prominently between the eyes, boss-like, lateral margins parallel, upper margin V-shaped the apex of the V lying between the antennal bases. Eyes blackish-brown, the margins appearing brown in certain lights. Antennæ black with the exception of the basal or two basal segments, which are brownish-yellow in some recently-emerged individuals, clothed with a dense pale-yellowish pubescence. Palpi and mouthparts yellowish-brown to blackish, hairs pale yellow. Hairs on clypeus, vertex, genæ and frons pale yellow, generally distributed on these areas with the exception of the frons, where they are confined to the lateral margins. *Thorax:* ground-colour black, clothed almost uniformly with a pale-yellowish, closely-investing decumbent, short pubescence; a silvery-white pollinose area on either of the anterior dorsal angles of the mesonotum, separated from each other by a rather broad, longitudinal stripe of ground-colour extending antero-posteriorly in the median line about one-third the length of the mesonotum; these areas most prominent when the specimen is viewed from behind; remainder of mesonotum is bedusted grayish-white to grayish-brown with a greenish tinge discernible in some, the pollinosity being best observed when the specimen is viewed from in front. Scutellum bedusted grayish-white with erect elong-

ated pale whitish-yellow hairs mostly confined to the margins and similar to the few, likewise erect hairs on the posterior region of mesonotum; prescutellar depression devoid of the long, erect, black hairs characteristic of *arcticum*. Pleuræ bedusted silvery-gray, membranous patch brown; pleural tuft pale yellowish-white. *Abdomen:* ground-colour yellow in recently emerged individuals, overlain dorsally in segments 1 to 9 inclusive by broad, transverse bands of grayish-black with but a narrow, posterior, yellow margin dorsally, in each segment; segments 2-7 yellow ventrally; segments 8 and 9 entirely black; second segment about three times as broad as the first, and dark band not extending so far laterally as in segments 3, 4 and 5, also less distinct. In pinned specimens the general colour is grayish-black; basal and second segments paler than the remaining ones; both are pollinose in certain lights, a silvery quadrangular area being especially distinct in gorged individuals occupying the median dorsal area of segment 2; segments 3, 4 and 5 dull black, each with a somewhat rectangular, dull-black area on the

Fig. 1.—*Simulium simile:* A, adult female. Greatly enlarged. B, egg x 90. (Original)

median dorsal surface and with pale yellowish patches posteriorly on the membranous sides; hairs pale and very short. Segments 6 to 9, inclusive, shining-black dorsally, clothed with sparsely-distributed, yellowish-white and a few black hairs much longer than those on the previous segments with the exception of the conspicuous, elongated fringe of yellowish-white hairs arising on either side from the dorso-lateral, posterior margins of the basal segment. *Legs* yellow, the following parts black: coxæ of middle and hind legs; femora except the bases and apical third of tibiæ of all legs; metatarsi of fore-legs and apical third of mid and hind metatarsi; the last four tarsal joints of all legs with the exception of the basal third of the second joint of the hind tarsi as far as the dorsal excision. Legs clothed with a rather long, pale yellowish-white pilosity. The relative lengths of the front tarsal segments (fig. 4, C) is as follows: 6, 3, 2.25, 1.5, 1.5. Claws (fig. 4, B) with a distinct tooth near the base. *Wings* clear, slightly iridescent, thick veins brownish-yellow. *Halteres* yellowish-white, brown at base of stalk. *Mouth-parts* (fig. 2): labrum epipharnyx (fig. 2, C, *le.*) attached to clypeus (*cl*);

unpaired, continued straight-forward from the head, delicate, chitinous plate strengthened medially and laterally by three densely-chitinised, longitudinal bars, meeting at the distal extremity in triradiate fashion; median bar extends posteriorly into the clypeus about one-third the length of the latter; a group of four retrorse denticles on either side of median line at the distal extremity, the most anterior of the four in each group being the largest; on either side, the distal margin bears a group of about seven or eight delicate hairs, which are probably sensory; just internal to each lateral, longitudinal chitinisation is a row of about twenty short, stout, peg-like spines arranged in open series; immediately posterior to the stout, anteriorly-placed denticles there is a pair of small spines on either side of the central, longitudinal chitinisation. Mandibles (fig. 2, A) paired, attached one on either side of the epipharynx,

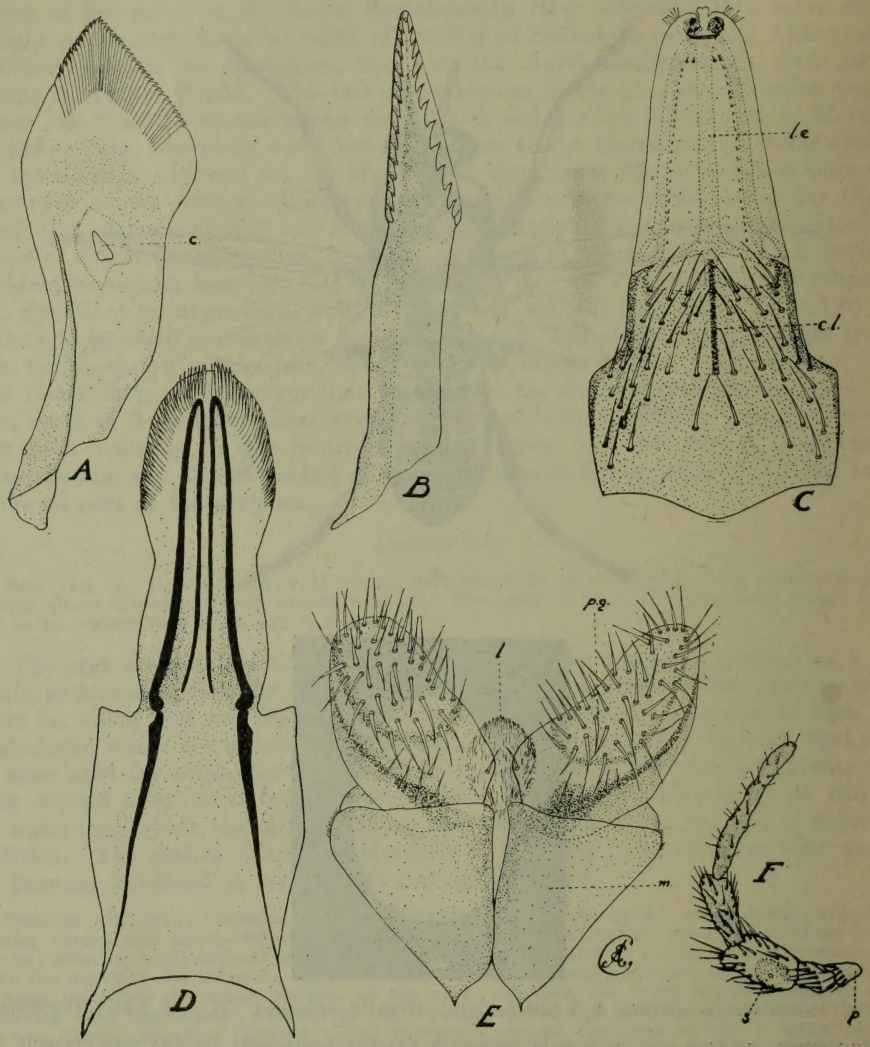


Fig. 2.—*Simulium simile*, adult, female mouth-parts: A, right mandible, ventral aspect, *c.*, crystal-like body; B, left maxilla, ventral aspect; C, upper lip, *l.e.*, labrum epipharynx, *cl.*, clypeus; D, hypopharynx; E, labium or lower lip, *l.*, ligula, *pg.*, paraglossa, *m.*, mentum; F, labial palp, *s.*, sensory organ, *p.*, palpiger. All greatly enlarged. (Original.)

spatuliform, strongly chitinised basally; outer basal margin involuted dorsally for about one-third of its length; the V-like apical extremity with serrated margins, striæ proceeding proximally for a short distance from the intervals between the individual teeth; inner margin with about twenty-six teeth, outer margin with about twelve. About midway between the base and the distal extremity in the centre there is a pale, transparent, pentagonal area, which extends about two-thirds across the breadth of the mandible, limited anteriorly by a rather broad suffused-brown band extending from one margin to the other; at the centre of this area is a

triangular, refractive, crystallike body (*c*). Maxillæ (fig. 2, B) paired, arising somewhat ventral and lateral to the mandibles, dorsal to the hypopharynx; slightly shorter than the mandibles, ensiform; inner margin more strongly chitinised than the outer and involuted ventrally; a longitudinal series of retrorse teeth borne on either margin of the apical third, about thirteen on the inner and sixteen on the outer margin; the odontophore margins are involuted ventrally. Labium (fig. 2, E) ventral to other mouth-parts, its two halves partly embracing the closely-applied hypopharynx and epipharynx; mentum (*m*) consists of two, imperfectly-fused triangular plates, each one articulated distally to the soft, cushion-like paraglossa (*pg.*) of its side: the latter broad and flattened on its medial surface and bearing numerous sensory hairs. Ligula (*l.*) unpaired, ovate membrane, longitudinally rugose, arising from the mentum in the median line and lying between the paraglossæ beneath and hypopharynx above; capable of lateral expansion; its wrinkled, transparent surface gives it the appearance of a dense group of delicate hairs. Hypopharynx (fig. 2, D) unpaired, median part equal in length to the epipharynx and forming with the latter a tube enclosing the mandibles and maxillæ; extends beyond the paraglossæ distally by about one-fourth the length of the latter; attached basally to a rectangular, basal plate almost as long as the epipharynx itself; on either side of the median line is an elongated, V-shaped chitinisation, the apex of the V directed towards the distal extremity, the outer arm of each being more strongly chitinised than the inner; general shape spatuliform, broad at the base, narrowing on either side midway and again broadening distally to end in a broadly-rounded, apical margin, which bears a closely-set series of elongated, sharply-pointed teeth (or spines) discernible only under high magnification. Palp (fig. 2, F) consists of a palpiger or basal segment (*p*) and four other segments; palpiger attached to mentum, equal in length to first segment of the palp; second segment twice as long as the first and about twice as broad; palpiger, first and second, segments densely clothed with very minute, cilium-like hairs and bearing a few sparsely-distributed, delicate, elongated hairs; second segment bears a well-developed, sac-like, sensory organ (*s.*) communicating with the exterior dorsally by a small round pore, the margin of which is beset by minute guard-hairs extending partway across the opening; third segment equal to the second in length, broadening distally; fourth segment about three times the length of the second, about one-half its breadth and thickest about one-third from the base. In addition to the irregularly-disposed, sparsely-distributed, elongated hairs on segments three and four, there is also an annuliform, closely-set series of minute cilium-like hairs, the annuli being interrupted here and there.

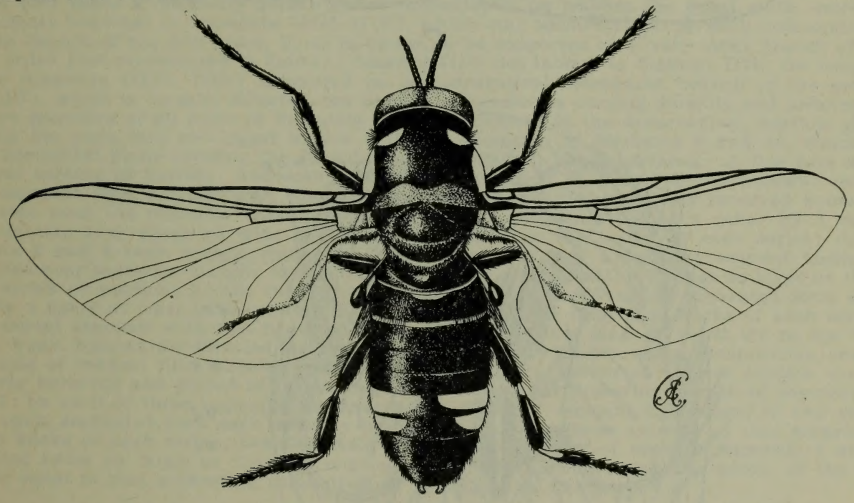


Fig. 3.—*Simulium simile*, adult male. Greatly enlarged. (Original.)

MALE (fig. 3). Length about 3 mm.; dull velvety-black. *Head* black. Antennæ black except the brownish-black basal segment, invested with pale-greyish pubescence. Frons and clypeus black, silvery dusted, a few black hairs emerging from the frons between the eyes; postocular hairs black. Eyes bronzy reddish-green during life, soon changing to black in death; upper eye-facets conspicuously large, the lower small as is typical of the genus. Palpi with palpiger and the two basal segments grayish-black as in the female. *Thorax* black; mesonotum invested with a close-lying, decumbent, golden pubescence that is less dense than in the female; scutellum and prescutellar depression bearing elongated, erect, black hairs and also a few decumbent hairs on the scutellum; a pair of triangular, shimmering, silvery spots on the mesonotum in front, broadly separated in the middle by ground-colour; lateral and hind margins whitish-pollinose in certain lights. Pleuræ grayish-white pollinose; pleural tuft sparse, pale. Scutellum devoid of pollinosity, velvety-black; postscutellum whitish-pollinose. *Abdomen* dull velvety-black above, venter of segments 2 to 5 greenish-gray during life, turning grayish-black in death; a silvery spot dorsally on either side of segments 2, 6 and 7, the pair of segment 2 united by a similar, transverse silvery bar anteriorly which is obscured by the overlapping posterior margin of the basal segment in dried specimens. Basal segment with pale grayish-white fringe of hairs about four times as long as that of the female; elongated, pale hairs also occur along the sides; segments 6, 7, 8 and 9 clothed with short, yellow, decumbent surface-hairs, which are represented but sparsely on the preceding segments. *Legs* more hairy than

those of the female; front pair black; coxæ brown; tibiæ silvery on the outside for the whole or at least two-thirds of their length; femora of fore and mid legs, tibiæ and tarsi of hind legs with long, black hair; middle and hind legs black, the basal third of mid tibiæ, basal fourth of hind tibiæ, basal third of mid metatarsi, basal half of hind metatarsi and base of hind second tarsal segment brownish-yellow; hind metatarsus (fig. 4, A) broadened, serrated ventrally, only slightly narrower than the thickest part of hind tibia, produced posteriorly and ventrally into a small lobe partly overlapping the base of the second joint with its characteristic dorsal excision. *Wings* as in female, membrane vitreous and likewise iridescent. *Halteres* pale chrome-yellow, deeper shade than those of female, stalk and its base black. *Genitalia* (fig. 4, D) almost entirely hidden from above by the overlapping ninth tergite (*t.* 9) as is characteristic

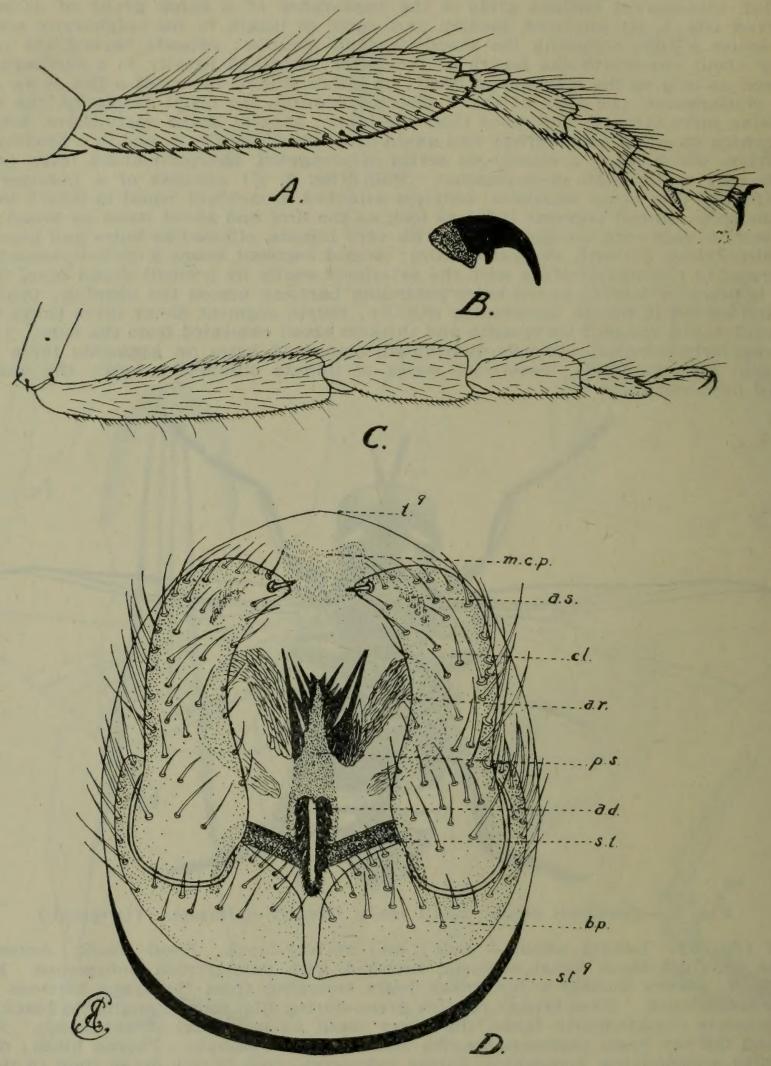


Fig. 4.—*Simulium simile*, adult structures: A, hind tarsus of male, metatarsal joint with ventral, serrated margin; B, claw of female showing sub-basal tooth; C, front tarsus of female; D, genitalia of male, *t.*9, posterior margin of 9th tergite, *m.c.p.*, median chitinous plate, *a.s.*, *appendices superae*, *cl*, clasper, *ar*, arm, *p.s*, penis sheath, *ad*, adminiculum, *st*, stylus, *b.p.*, basal pieces or *appendices intermediae*, *st.*9, rudimentary 9th sternite. All greatly enlarged. (Original.)

of the genus, but readily seen from below owing to the reduction of the ninth sternite (*st.* 9). Ventral, paired side-pieces most prominent of the hypopygial structures, each consisting of a basal lobe (*b.p.*) articulated with a clasper (*cl.*), black, clothed with black hair; basal lobes short, about one-third the length of the claspers but almost twice as broad, separated from

each other by a narrow suture. Claspers strap-shaped, slightly incurved towards the margin of the ninth tergite, broader basally than distally and terminating in either a bluntly-rounded or sharply-pointed apex directed mesially and bearing a short, stout spine as illustrated; distal to a perceptible slight prominence near the base, the inner margin is embayed. The hairy *appendices superæ* (*a. s.*) are situated dorsally just behind the margin of the ninth tergite, each one of the two overlapped by the extremity of the clasper of its side, and less strongly chitinised than the larger black, intermediate plate (*m. c. p.*), which is merely pubescent. Adminiculum (*ad.*) black, invested with a fine pubescence, recurved, emerging between the bases of the claspers mesially, narrowly triangular and trough-like, lateral margins bearing each about six teeth; apex bluntly pointed; the two limbs of the stylus (*st.*) of the adminiculum arise dorsal to the basal lobes of the side-pieces. The "arms" (*ar.*) lie ventral to the *appendices superæ*, consisting on either side of a somewhat S-shaped rugose, chitinous thickening of the hypopygial membrane; mesially, where the arms meet, are three pairs of stout, sharply-pointed spines, of which the dorsal pair are smaller than the others; also a variable number of supplementary spines arising at the base of the larger ones. Lying between the spines of the "arms" and the adminiculum in the median line is a broad, weakly-chitinised structure, the penis-guard (*p. s.*), extending inwards. *Mouth-parts* similar in all respects to those of the female save in their weaker structure; dental armature of the female parts replaced by hairs; sensory vesicle of second segment of palp smaller than that of female and aperture likewise smaller.

Pupa (fig. 5).—Yellow, head and thorax faintly tinged with brown; antennæ, mouth-parts, legs, wings and dorsal posterior border of thorax demarcated by a fine, brown, marginal line. Respiratory organ (fig. 5, A) about one half the length of the pupa, pale yellow to brownish-yellow, divided normally into twelve slender filaments. The basal stalk (*b.s.*) soon divides into three main divisions or branches of the first order (I^a, I^b, I^c); the ventral one (I^a) extends anteriorly almost vertically for a very short distance before dividing into two branches of the second order (II^a, II^b), of which the first (II^a) is ventrally inclined, the second (II^b) almost vertical; each emits two ultimtae filaments or branches of the third order (III^1, III^2, III^3, III^4); the middle division (I^b), slightly dorsally inclined, dividing almost immediately into two, short branches (II^c, II^d), of which one (II^c) lies lateral to the other (II^d); each of these again divides into two ultimate branches (III^5, III^6, III^7, III^8,); the third division (I^c) takes a decidedly dorsal course immediately on leaving the basal stalk, emitting two ultimate branches or filaments (III^9, III^{10}), which may apparently arise each independently from the branch of the first order, I^c, as in figure, or be supported on a very short branch of the second order (not represented in figure); filament III^{10} lies lateral to filament III^9; the remaining two filaments (III^{11}, III^{12}) supported on a comparatively elongated branch of the second order (II^f), which is dorsally directed, the filaments themselves curving dorsally and anteriorly; each two members of all pairs of filaments lie approximately in the dorsoventral, vertical plane bisecting the pupa into two equal halves with the exception of filaments 9 and 10, which lie in the horizontal plane dividing the dorsal from the ventral, pupal surfaces. A few pale hairs on dorsal surface of thorax. Abdomen with armature (fig. 5, B, C and E) as follows: second dorsal segment with a transverse, linear series of three, minute, anteriorly-recurved hooks on either side near the posterior margin, the two series separated from each other by a space approximately four times as wide as the space separating the hooks of each series; dorsal segments 3 and 4 each with a transverse, linear series of four anteriorly-recurved hooks on either side near posterior margin, hooks all equal in size and about three times as large as those of the series of segment 2; the two series of each of segments 3 and 4 separated from each other by a space at least twice as wide as that separating the individual hooks of each series; eighth dorsal segment with two transverse series, one on either side, of about six to ten very minute, weak, backwardly-directed hooklets; apical segment with two short, stout spines, one on either side of median line, directed posteriorly and mesially; hooks of ventral surface are all anteriorly recurved and placed in transverse, linear series near posterior margin of segments 5, 6 and 7; on each of these segments are four hooks, those of segment 5 arranged in two series of two each, separated from each other by a space about eight times as wide as that separating the two hooks of each series; the uniserial, equally-spaced hooks of each of segments 6 and 7 are about twice as large as those of segment 5, the distance between the hooks of the one segment equal to that separating the individual hooks of the other.

In regard to the filaments it should be noted that variations in the number are not exceptional. Specimens with thirteen filaments on one side and twelve on the other have been sometimes encountered, and also a single specimen with eleven filaments on one side. Apparently a variation in the number of one set does not necessarily mean a variation in the number of the other. In one instance fourteen filaments were counted due to an abnormality of filament 12, which distally gave rise to a diminutive branch before terminating in a bifurcated extremity. The complete absence of filaments on one side was noted in two specimens, but I was unable to decide whether this abnormality was the result of an accident or due to retarded development. From the fact that the occurrence of more or fewer than twelve filaments is rare and that the variation may only extend to one of either sets, I have no hesitation in maintaining that twelve is the normal number for *S. simile*.

Cocoon (fig. 5, D and F).—5 mm. long by 2 mm. broad; tough, brownish-gray, semi-transparent membrane of closely-woven fibres, about two and one-quarter or two and one-half times as long as its breadth in region of pupal thorax, where height and breadth are about equal; arched upper surface gradually increases in height from behind forwards until the maximum is

reached in a rather abrupt gradient terminating in the anterior margin, which is thickened dorsally and laterally but thin ventrally, where it is often, but not invariably, emarginated in V-fashion (fig. 5, F); lower margin thickened, bearing a narrow, inwardly-projecting shelf all around; posteriorly, the shelf of one side united with the shelf of the other by a loosely-woven, thin, fibrous membrane forming a floor, which entirely or partially covers the ventral surface of the pupal abdomen, but is absent in the region of the thorax; anteriorly, the more densely-woven floor is raised at an acute angle with the remainder (fig. 5, F) so that the cocoon is

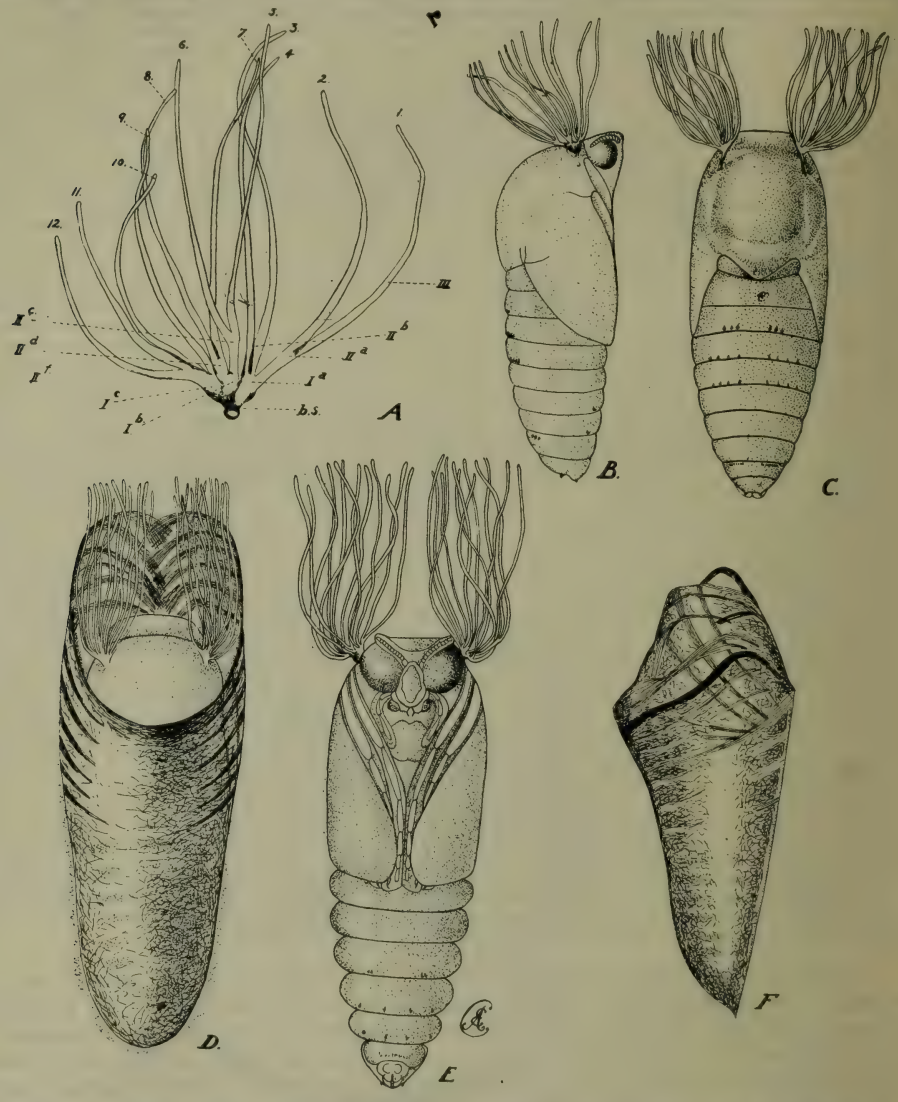


Fig. 5.—*Simulium simile*, pupa: A, respiratory organ, I^a, Ib, Ic, branches of first order, II^a, II^b, IIc, branches of second order, III^1, III^2, III^3, etc., branches of third order or ultimate filaments, which are indicated by Arabic numerals (1 to 12) beginning from ventral side; B, pupa, lateral aspect; C, pupa, dorsal aspect; D, pupa within cocoon, dorsal aspect; E, pupa, ventral aspect; F, cocoon, lateral aspect. All greatly enlarged. (Original.)

boot-shaped; a few separate, reinforcing, transverse bands immediately behind and parallel with the interior margin crossed at intervals by similar longitudinal bands forming the frames of several "windows"; anterior opening oval, exposing the head, thorax and respiratory organs (fig. 5, D).

LARVA (fig. 6).—Length 6 mm., greatest breadth 1.25 mm. General colour grayish-green with imperfect, stippled, tranverse bands of olive-green pigment on the segments, more accentuated dorsally than ventrally: bands more or less interrupted along dorso-median line, and ventral surface of last four abdominal segments almost or entirely devoid of pigment; some

individuals almost or entirely immaculate. *Head* pale yellowish, posterior margin of capsule black except behind the clypeus, very faintly darkened laterally around the paired, black eye-spots; posterior clypeal margin with transverse band, somewhat darker centrally than laterally; anteriorly, an H-shaped mark discernible with posterior halves of the limbs less distinct, broader and more widely separate than the anterior; midway between the limbs is a longitudinal series of small, transverse spots, rather indistinct posteriorly; two or three small dots sometimes apparent anteriorly on either side between the H-shaped mark and the lateral margins of clypeus and closely adjacent to the former. Antenna (fig. 7, D) 4-jointed, tapering gradually to the end of the second, which bears the 2 apical sense-cones (*s.c.*) characteristic of the genus.

Fig. 6.—*Simulium simile*, full-grown larva, *h.f.*, head fan, *r.g.*, rectal gills, *a.s.*, anal sucker. Greatly enlarged. (Original.)

second joint slightly less than twice the length of the first or third, which are subequal; third about one-half the width of the second; fourth minute. Fans (fig. 6, *h.f.*) with about 55 golden-yellow rays supported on a brownish-yellow stalk, fringed on the inside by exceedingly minute, equidistant, erect hairs of equal length. *Mouth-parts* (fig. 7) brownish-yellow to brown; mentum (fig. 7, A) double, subtriangular plate, truncated apical margin with 9 simple, black teeth, the central one and that at each end considerably larger than the others; central tooth most pointed;

sides of mentum with 4 or 5 elongated hairs; lateral margins serrate distally: labrum (fig. 7, F) short, rounded, fringed with elongated hairs, reinforced by a T-shaped sclerite (*t*) with divergent, proximal, elongated arms; dense, aigrette-like group of hairs just anterior to base of sclerite; apical margin irregularly serrate; mandibles (fig. 7, C) thumb-like, densely chitinised, outer lateral margin rounded, inner more or less rectilineal, apical deeply emarginated; apical teeth of varying strength and size. three distal ones largest, proximal to which are three smaller and paler teeth followed by a series of about ten sharply-pointed teeth; immediately lateral to this last series on the inner margin of the mandibles are two pale teeth with broad bases, of which the anterior is about twice as large as the posterior; a brush of stout hairs arises from

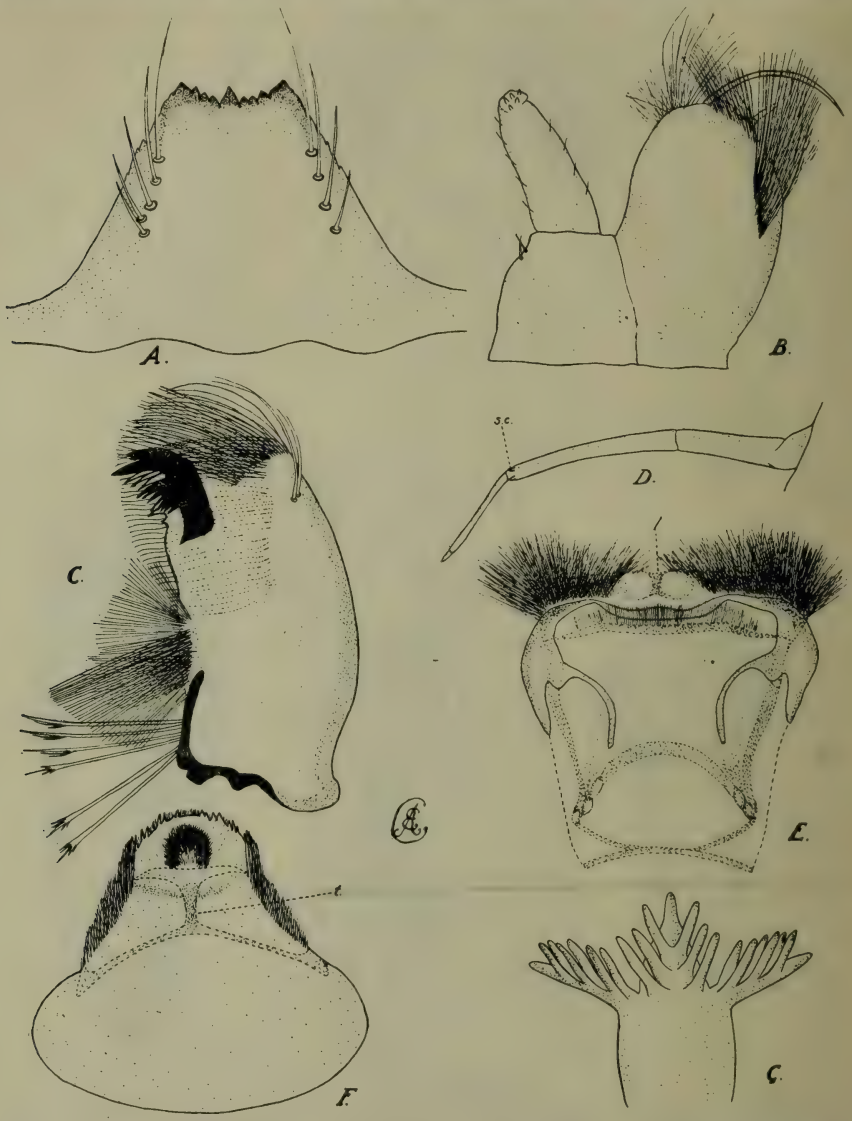


Fig. 7.—*Simulium simile*, larval structures: A, mentum; B, maxilla; C, mandible; D, antenna, *s.c.*, sensory cones; E, hypopharynx, dorsal aspect, *l.*, ligula; F, labrum, *t.*, t-shaped sclerite; G, rectal gills. All greatly enlarged. (Original.)

the apical margin, directed mesially and surmounting the apical teeth; commencing at the apex and extending about half-way to the base is a comb-like series of elongated, delicate hairs directed mesially, over-lapping and partly obscuring the apical teeth; they originate near the centre of the body of the mandible; proximal to this comb are two fan-shaped groups of hairs, of which those of the distal group tend to radiate anteriorly, those of the basal group posteriorly; from the inner, basal ,stoutly-chitinised margin a series of six very long, large, hollow hairs originates, directed mesially and posteriorly, branched at apex; two large, curved, bristles arise close

together near the apical margin and just within the outer lateral margin at its distal end: maxilla (fig. 7, B) consists of a 2-segmented palp and a flat, rounded, undivided lacinia; basal joint of palp about twice the breadth and three-quarters the length of the apical, which terminates in a small, rounded prominence bearing about six cone-shaped protuberances similar to those on the apical end of second antennal segment; lacinia beset with fringes of long hairs; emerging from the hairs distally is a stout, elongated, sickle-shaped, transparent spine directed mesially; slightly proximal to it is a smaller stout, blunt spine apparently arising from a small protuberance: labium hypopharynx (fig. 7, E) fleshy, re-inforced by a chitinous framework, apical margin with two brushes of hair, one on either side, between which are the two delicate, transparent, rounded lobes of the ligula. Thoracic proleg sub-transparent, directed anteriorly beneath the head; anterior fourth elbowed, distal extremity crowned with a ring of minute hooks arranged in parallel rows. Anal sucker (fig. 6, *a.s.*) with about 95 rows of hooks, 12 to 18 hooks to a row. Rectal gills (fig. 6, *r.g.*, and fig. 7, G) trilobed, each lobe emitting six to eight small branches, with seven most frequently occurring. No ventral papillæ on last segment.

Life-history, Habits and Economic Importance

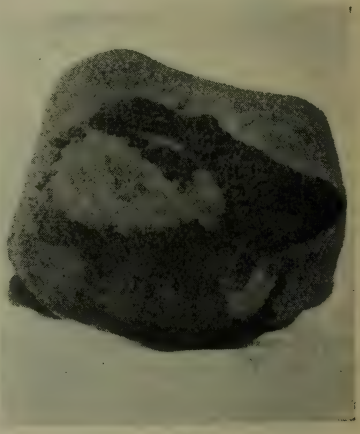
Habitat of Pre-adult Stages.—The egg, larval and pupal stages are found in the North and South Saskatchewan rivers, and up to the present I have not encountered them in any small streams that are tributary to these rivers in the province of Saskatchewan. In the language of the North American Indian, Saskatchewan means swift-flowing and the early stages of *S. simile* occur only in the swiftest parts, attached to water-worn stones. In these places the rapidity of the current is generally much increased, and the most ideal conditions (fig. 8, B) are presented where the water is obstructed in its flow by a projecting, stony arm of the shelving bank cutting diagonally upstream into the river. Such an obstruction serves to dam the water, which is released over the natural breakwater with a swiftness essential to the successful breeding of the larvæ. These stony barriers (fig. 8, A) occur at frequent intervals along the banks of both rivers, and throughout the summer and early autumn *S. simile* breeds in great abundance in these places. Some of the stones are literally coated with dense colonies of the larvæ and pupæ both near the bank just below the surface of the water and further into the stream at depths of four or more feet beneath the surface.

In order to understand more clearly certain phenomena of the life-history, it should be explained that the Saskatchewan rivers are completely frozen over for a period of about five to five and one-half months, extending from about the middle of November to the end of April. When the rivers thaw, the broken ice does not move freely at first, and, consequently, the pent-up waters rise rapidly until the flood water-level is reached. The force exerted on the ice by the mounting head of water gradually clears the obstruction, and the rivers slowly subside during May. Towards the end of May and beginning of June the water rises to flood-height again owing to the melting of the snows in the Rocky mountains at the source of the rivers. This condition of high-water may continue for several days, but there is generally a decided decrease before the end of June or beginning of July. The volume may again increase owing to the effects of heavy rains, so that in some seasons the water remains high during the first half of July and, exceptionally, until the end of July. Subsequently, until winter arrives, the waters remain very low, indicated by the appearance of sand-bars here and there above the water-level. Any rise that occurs during August to November is fleeting and appreciably slight in its nature.

Seasonal Cycle.—First-stage larvæ are found first about the beginning of June in each year, when the temperature of the water has increased to about 50°F. The temperature continues to mount until it reaches an average maximum of about 70° to 75°F. during late June, July and August. This increase coincides with an increase in the numbers of the larvæ and pupæ, which are only limited by the sudden falling of the water. During the summer months the larvæ complete their growth in a period of about three to four weeks, during which they undergo six moults previous to the assumption of the pupal stage. The duration of the various larval stadia are not easily determined in the Simuliidæ owing to their peculiar habit of living only in fast-running water. The moulted larval skins are quickly washed away, but the

A.

B.



C.

Fig. 8.—*Simulium simile*, habitat of pre-adult stages: A, South Saskatchewan river at Saskatoon showing a stone-barrier directed upstream from south bank and exposed at low-water mark; photograph taken from downstream side of barrier; B, the same at high-water mark, showing the rapids passing over the barrier; photograph taken from upstream side; C, stone from rapids encrusted with coral-like mass of cocoons containing the pupae; reduced to about one-eighth. (Original.)

terminal sucker adheres to the surface of its attachment. As this organ increases in size from moult to moult, I have been able to determine the number of moults by making a series of measurements of the effete suckers. The pupal stage lasts for five to seven days, at the end of which time the adults emerge. I have been unable to determine the duration of the egg-stage, but in the summer months it would not certainly be longer than seven days, the time stated by Pomeroy * and Malloch † for the species of Simuliidæ in general. Altogether, there are at least four generations in central Saskatchewan, but owing to variations in the times of development of the different stages, the dates of appearance and periods of persistence of the various generations are not well-defined. This is also in part due to the fact that the ovaries of the adult females of any one generation do not mature at the same time, and consequently the egg-laying period is distributed over several days. For example, during the summer of 1918 swarms of adults were a common occurrence almost every day from the date of their first appearance on June 7 until September 16. Straggling individuals continued to occur in smaller numbers as late as October 15, when the last adult female was observed. On dull, windy days, when swarming did not occur, the adults could invariably be found resting in large numbers on the outside of the wire-screening protecting the verandahs of dwelling-houses and likewise on the wire-screened walls of the insectary on the campus of the University of Saskatchewan. During the previous year, 1917, the almost daily occurrence of numerous adults was noted, but in 1919, 1920 and 1921 periods of several days passed at intervals during the summer months, when very few if any specimens could be found. After examining all the evidence at hand, I have decided that the explanation of this variation in numbers from year to year may be accounted for by the influence of two principal, adverse factors, namely, (1) severe winter conditions, which curtail the numbers of the first generation in June, and (2) the great mortality caused by the periodic, sudden fall of the water-level throughout the summer, which leaves the larvæ on the stones nearest the banks stranded high-and-dry and exposes them to the fatal effects of dessication. Other factors of lesser importance are the comparative abundance of predaceous, aquatic insects, which live in association with *S. simile* and feed extensively on the larvæ, as well as of certain species of fish, which greedily devour them.

Larvæ in all stages of development and pupæ are found during June, July, August, September and, in mild autumns, a few may occur in the early part of October. As a general rule, however, they disappear completely when the temperature of the water falls below 50°F., and no trace of them is to be found until the following summer. Although temperatures have a direct relation to the support of the life-processes of the organism of the larva, the factor, which is of prime importance in the determination of their numbers, is the height of the water-level. As has been already indicated, the water recedes during late summer, uncovering the breeding-places and leaving them exposed until the river becomes frozen over in November. Any larvæ and pupæ, that remain, are thus killed off by the withdrawal of the water, although some of the pupæ, that are almost mature, may contrive to transform to the adult stage. It is practically certain that no larvæ or pupæ remain in the river during the winter, and, as the species re-appears next summer as a first-stage larva, it is probable that *S. simile* winters over in the egg-stage. In support of this hypothesis I have nothing but circumstantial evidence to offer. Further, it is feasible that the eggs embedded in the protecting matrix, which, although provided with only a thin shell, may be resistant to zero temperatures, may also be capable of withstanding prolonged periods of dessication as has been suggested by Edwards for the eggs of *S. latipes*.‡

To this conclusion we are drawn by the fact that during the summer months, when the breeding-places are left exposed by the receding water for periods of two to three weeks at a time, they may be found to contain thousands of first-stage larvæ a

* Pomeroy, A. W. J.—"Notes on five North American Buffalo Gnats of the genus *Simulium*." U.S. Dept. Agric., Bull. 329, 1916, p. 26.

† Loc. cit., p. 8.

‡ Edwards, F. W.—"On the British Species of Simulium.—II. "The early stages; with corrections and additions to Part I." Bull. Ent. Res., vol. XI, pt. 3, p. 240.

few days after the water rises again and covers the stones. The re-establishment of favourable, environmental conditions would stimulate the process of hatching and emergence of the larvæ from eggs, that may have been laid either clear of the water entirely or on stones water-washed at the time of oviposition, but left dry for a time during the recession of the water. As regards the former of these alternatives, I may say that I have on no occasion observed females ovipositing on dry stones or boulders on the river bank, but the fact that colonies of recently-emerged larvæ are frequently found on these stones when the water again rises and sweeps over them, is in my estimation at once significant and suggestive. If only a few larvæ were found under these conditions, one might imagine that they had been accidentally carried downstream from some more favourable breeding-location, but the large numbers and uniform age of the individuals of these colonies seems to preclude effectively the feasibility of such a chance migration of isolated larvæ offering an adequate explanation of all the facts.

The larvæ and pupæ are generally attached to the stones with their heads directed downstream.

Range of Flight and Swarming.—The adults of *S. simile* are frequently found in large numbers at distances of 12 to 15 miles from their breeding-places. On June 8, 1918, a visit was made to Rosthern and Duck Lake, about 40 and 50 miles respectively northeast of Saskatoon on the branch of the Canadian National Railway, that connects Saskatoon with Prince Albert. Rosthern lies about 9 miles due west of the South Saskatchewan river and Duck Lake about 5 miles. On this particular date no adults could be seen in either of these townships. On June 9, a visit was made to the river at Fish Creek 12 miles southeast of Rosthern, when the first generation of adults was emerging from the water and taking flight. The flies were observed to make their exit from the pupal cases and bear themselves up to the surface by means of the buoyant agency of an enveloping bubble of air. Almost immediately they departed on the wing, but large numbers were unsuccessful in making this initial flight and being carried downstream by the current were ultimately drowned. As a result, there was a strip 2 to 3 feet wide composed of the dead, washed-up bodies of the adults, running along the sloping, stony bank close to the water's edge for a distance of several hundred yards. Those that were successful in taking wing, were at once borne away in a north-westerly direction by a strong southeast wind, that averaged 7 miles per hour. The emergence-flight continued from 3 p.m. to 5 p.m., the temperature being 98½° F. It was again observed on the following afternoon, when conditions were practically similar, and also on June 14. The discovery of the adults at Rosthern, 12 miles distant in a north-westerly direction, on the following day, did not furnish cause for surprise under these conditions. They were also encountered in dense swarms on the Indian reservation west of Duck Lake and about 10 miles due west of the river. There can be little doubt but that the wind is the chief agent in the dissemination of the adults, although I have frequently observed that they seek the shelter of trees and shrubs when the wind develops into a gale accompanied by an overcast sky and air-temperatures below 70° F.

Practically on any favourable evening from June to September swarms of black-flies may be observed in close proximity to their places of breeding. Records were compiled daily during these months in 1918, and on almost every day and evening the swarming habit was observed from June 3 to September 16. Swarming may occur at any hour of the day on the open prairie, where cattle and horses are grazing, and the animals are often enshrouded in a shimmering haze of flies, especially when the weather conditions are bright and warm. These swarms may extend for several feet around the animals and also for some distance into the air (fig. 9, A). At 11 a.m. on July 5, 1918, a very dense swarm of flies was observed enveloping the forms of a dozen head of cattle and horses in a pasture 10 miles due south of Saskatoon. The animals were congregated together on the site of a burnt-out "smudge" in the field. The flies hovering over the cattle emitted a distinct, low-pitched, humming note somewhat like that produced by a swarm of bees but much more faint. As the breeze veered this way

and that, the swarm was observed to change its position slightly, at which time the humming sound became momentarily accentuated. The swarm was observed to be composed of females mostly, and those, that were captured and examined, had all apparently partaken of a blood-meal. Very few males were seen. Similar swarms have been frequently observed on other occasions in 1917, 1918, 1919, 1920 and 1921 around cattle and horses in the vicinity of Saskatoon, at Rosthern and Duck Lake, June 8, 1918, Carlton, June 23, 1918, and again at Rosthern on June 26, 1918.

Large swarms of *S. simile* also occur independent of the presence of horses and cattle. These swarms may consist of males only or a mixture of males and females and are to be found on any warm evening, generally between the hours of 4 p.m. and 9 p.m., especially after a shower of rain. On warm, cloudy days with rain threatening or falling gently these swarms have been observed in the forenoon and afternoon, Rosthern 10 a.m., 28. VI. 18, Saskatoon 3 p.m., 23. VIII. 18 and 11 a.m., 24. VIII. 18. The height of a swarm may extend into the air for a distance of 50 feet or more, and in a mixed swarm the males most generally occur in the lower zones. Such swarms are almost invariably found in close proximity to buildings and dwelling-houses, where they may find shelter from the buffeting of the wind, and they also occur near tall-growing shrubs such as caragana bushes.

Under unfavourable weather-conditions, such as windy and wet, cool days, *S. simile,* both males and females, has the habit of congregating on the outside of the protecting wire-screening of verandahs of dwelling-houses, where they remain more or less passive. They are also found resting on the leaves of shrubs and, on occasions, they enter the rooms of dwelling houses in large numbers through the open windows. At the University of Saskatchewan they make their way into the laboratories in similar fashion, where they are found on the inside of closed windows. If they are not permitted to escape, they generally die in two or three days.

Proportion of Sexes.—Between the dates of July 20 and August 10, 1918, 1,150 adults were reared from larvæ in the laboratory breeding-tanks. Of these there were 544 males and 606 females. These figures I consider to be sufficiently close to warrant the conclusion that in any one generation the sexes are about evenly distributed. At the time of emergence of the first brood at Fish Creek on July 9, 1918, it was observed that the flies congregated in large numbers on the dry, shady side of stones on the river bank, that were only partly immersed in the water. The males were observed to predominate, and it seemed as if they constituted the larger proportion of the early individuals of the initial brood. As the females, however, appeared to take flight from the breeding-grounds much more readily than the males, this seeming disproportion could not be accurately gauged.

Food of Larvæ,—The contents of the alimentary canal appear yellowish through the more or less transparent body-wall. Microscopic examination showed that the colour belonged to the very minute particles of silt, that are extracted from the river water, which is at all times heavily laden with this fine, inorganic debris. Several authors have dealt with the constituents of the larval food as indicated by Pomeroy,* but I cannot agree with this author that the larvæ of Simuliidæ appear to thrive best in those streams that contain the largest proportion of such organisms as *Euglena viridis* and *Spirogyra.* Investigation of this supposition relative to *S. simile* showed that the larvæ flourished quite well where these organisms were absent, and, in fact, they very rarely occurred near the breeding-places. A species of blue-green alga of the family Chroococcaceæ covered the stones as a gelatinous stratum in the late summer, and larvæ were seldom found to occur on such coated stones. Of the diatoms that formed the main components of the food, *Nitzschia linearis* Smith was the most abundant and greatly outnumbered *Gomphonema acuminatum* Ehrenberg and *Navicula rhynchocephala* Kützing, which were usually but sparsely represented. As regards the effect of sewage on the larvæ, I have found that it is not apparently deleterious to their activities, although it must be stated that one extensive breeding-ground, which occurred in

* Loc. cit., p. 22

the river at Saskatoon (fig. 8, A and B) lay almost a mile downstream from an outfall sewer. By the time the sewage had traversed this distance, it had become considerably diluted and distributed by the current, so that the larvæ were not subjected to the full effect of the noxious waste-substances.

Food of Adult.—The adult female has become an habitual and inveterate blood-sucking insect, the activities of which have occasioned much concern among the farmers of Saskatchewan in recent years. The hosts include cattle, horses and mules, but there is no evidence that human beings are molested. Cattle are much more troubled than any other host, but the regions selected for attack are the same in all cases, namely, the forequarters and under-surface of the belly. I have frequently observed the flies to be so numerous on these parts of cattle that the hosts appeared as if plastered with them. Their attacks are notable because of their tenacity and persistence, and once the mouth-parts are firmly inserted into the skin, the insect is not readily disturbed. Cattle may express their annoyance by lowing and straining at their tethers, if they happen to be staked, but, generally, they appear to adopt a passive attitude towards their tormentors, unless the latter are so numerous and the enveloping swarms so thick as to interfere with the grazing of the animals. In a previous short paper (1918)* I remarked on the loss of blood that oozed from the innumerable punctures and lacerations, and there can be little doubt that the amount extracted by the insects in feeding is a serious drain on the vitality of the host, especially when the attacks may continue for several days at a time throughout a period of four months. In addition to the parts above-mentioned, the flies also readily attack cattle in the region of the udders and the inguinal region of horses and mules.

Many reports have been made by agriculturists at various times concerning the fatal results following serious epidemics of *S. simile* in Saskatchewan. Unfortunately these losses occurred either before my arrival in Saskatchewan in 1917 or, in subsequent years, have been brought to my attention too late to allow of my making a first-hand investigation. In 1913, it has been stated on excellent authority that farmers of the Duck Lake district suffered the loss of about 100 head of cattle, horses and mules, and isolated instances of smaller losses have been reported from the Carlton and Rosthern districts in later years. On July 28, 1917, Dr. McLachlan, a practising veterinary surgeon of Rosthern, stated that he had been consulted on several occasions concerning the fatal effects of *S. simile* attacks. The symptom, which was most marked according to this observer, was a swelling of the belly and inguinal region, as also of the breast and muzzle. It was suggested that the direct cause of death might be due to suffocation following the entrance of large numbers of flies into the respiratory passages through the nostrils. In my experience I have found that the flies do not apparently enter the nostrils voluntarily. It has, however, been frequently observed that, where cattle are enveloped by dense swarms, the irritation caused by the insects flying in close proximity to the nostrils stimulates the excited animals to quicken their respiratory movements, an action which is accompanied by a straining forward of the head. It is quite possible that the flies may be inhaled, a supposition that is supported by the intermittent violent snorting and coughing of the cattle, as was observed on July 5, 1918, among cattle in a pasture 10 miles south of Saskatoon. Some of the animals in this case appeared to be exhausted by the attacks and lay resting on the ground with heads outstretched, rubbing their chins every now and then in the dust-strewn remains of a straw-fire.

I have never found that *S. simile* will attack human beings. The females have, on occasion, a disconcerting habit of flying around one's head and person, and this has been observed in the case of those individuals that have entered houses as well as in the open. At Fish Creek on July 14, 1918, during the emergence of the initial brood, males and females frequently settled on the clothes of other observers as well as myself, but in no instance did the females offer to bite. A portion of a swarm infesting cattle will sometimes follow a human being for some distance, but the individuals

* Loc. cit., p. 5

generally maintain themselves at a short distance above the person's head and rarely settle. In the evening towards dusk I have frequently observed the females in numbers flying around my head, and they would occasionally alight on my face and shoulders, especially when I assumed a stooping position in the performance of some gardening task. No member of the Simuliidæ has been so far successfully identified with the transmission of pathogenic micro-organisms from one host to another. The sudden deaths amongst live-stock in districts, where *S. simile* was prevalent, warranted an investigation into the possibility of its being a vector of some minute blood-parasite of its mammalian hosts. Numerous blood-specimens taken from animals, that had been badly bitten, failed to reveal any trace of a destructive organism, and an examination of the stomach-contents of females of *S. simile* that had partaken of a blood-meal, also yielded evidence of an entirely negative character. Blood-counts seemed to show that there was a slight increase in the number of eosinophil leucocytes in the blood that had been drawn by the females as compared to normal blood, accompanied by an appreciable increase in the polymorphonuclears and mononuclears also. The area immediately surrounding a puncture becomes œdematous, and the exuded serum becomes hardened on the surface. Where numerous bites are inflicted close together in the same region, an extensive œdema results owing to the confluence of the developing lesions, and the whole area becomes encrusted with dried serum, which has oozed out from the punctures. Later, when the swelling subsides, each puncture becomes the site of cicatricial changes of the superficial tissues.

A suggestive paper by J. H. Stokes,* reviewed by Riley and Johannsen,† treats of the histopathological changes and clinical symptoms of the black-fly *(S. venustum)* bite. What is more interesting, however, is the fact that the author was able to reproduce experimentally by the hypodermic injection of various extracts of dead flies—especially from the head and thorax—the characteristic lesions, which follow the puncture of the fly in nature. As regards the action of the unknown toxic agent, it is suggested that this may be liberated from the injected saliva by the lytic action of the host's serum, and that the eosinophiles are chemotactically attracted to the site of its liberation, where they help to neutralise it. On the other hand, the toxin may be present in the saliva from the first, when the eosinophiles would perhaps play the part of direct neutralising agents and thus set up a condition of immunity, if particularly numerous in the host. Another suggestion is that the effects of black-fly bites might be explained on the general basis of anaphylaxis, an initial injection of a foreign, proteid substance establishing a condition of sensitisation in the host, which is followed by a specific and well-marked series of reactions on the occasion of subsequent injections of the same protein. As remarked by the author (Stokes), it is not improbable that the cutaneous rashes, which follow insect bites in general, may find a satisfactory explanation on the basis of anaphylactic phenomena. The "hypodermal rash," which follows the penetration of the skin of cattle by recently-hatched warble larvæ, may be similarly explained, as indicated by Hadwen.‡

Relation of Blood-Sucking Habit to Development of Ovaries

From a series of dissection of adult females in various conditions of engorgement, Pomeroy** has gathered evidence, which would seem to show that the state of development of the ovaries depends on the partaking and the degree of digestion of a blood-meal. In those individuals, which had not fed, the ovaries were quite rudimentary, and, although they might continue to live for a period of about five days, there was no change observed from the time of their emergence up to the time of their death. On the other hand, individuals that had been captured in the act of feeding, were found to

* Stokes, J. H.—"A Clinical, Pathological and Experimental Study of the Lesions produced by the Bite of the Black Fly (*Simulium venustum*)." Jour. Cutan. Diseases, Nov. and Dec., 1914.

† Riley, W. A. and Johannsen, O. A.—"Handbook of Medical Entomology," Ithaca, N.Y., 1915, pp. 321-326.

‡ Hawden, S.—"Warble Flies, *Hypiderma lineatum* Villers and *Hypoderma bovis* De Geer." H. of A. Branch, Dept. Agric., Ottawa, Scient. Series 27, 1919.

** Loc. cit., pp. 29-34.

have ovaries either rudimentary or partly developed according to the degree of digestion of the blood-meal. The longer the period during which digestion had proceeded, the larger was the number of completely developed eggs within the ovaries. The discovery of a few fully-developed eggs in the ovaries of those females which had just oviposited, together with a residuum of immature eggs, seemed to indicate that feeding might occur a second time after one act of oviposition and thereby determine the development of the remaining eggs, which would necessitate a second act of oviposition. The period between the ingestion of the first and second meals would serve for the incubation of any blood-parasites, which might be taken from the host, in which case the longevity of the female, together with the possibility of its being a plural feeder on more than one host, would increase its importance as a probable agent in the transmission of disease.

The results, which I obtained by dissecting out and examining the ovaries, support in the main those obtained by Pomeroy. One hundred and twenty-five female specimens of *S. simile*, classified into five groups of twenty-five each according to the state of engorgement, were dissected, and the ovaries carefully examined. The following brief summary will serve to indicate the correlation of ovarian development with the degree of digestion:—

1. *Unfed individuals, reared from pupæ and killed immediately on emergence.*—In all cases the ovaries were quite immature, the individual ova being difficult to distinguish.

2. *Unfed individuals, reared from pupæ and killed at varying intervals up to five days after emergence.*—No matter the length of the period between emergence and time of death, the ovaries remained in an unchanged rudimentary condition as in the case of group 1.

3. *Fed individuals, captured on cattle in the act of engorging.*—In the case of those specimens killed immediately on capture, the ovaries are generally immature with eggs quite rudimentary. In a few cases of specimens completely engorged, the ova appeared to be somewhat larger than those of unfed individuals, but no fully developed eggs were present in the ovaries.

4. *Engorged individuals captured on cattle and killed at intervals up to three days after capture.*—In no case was I successful in keeping engorged specimens alive longer than three days in moist glass-bottles, covered with cheese-cloth, in the laboratory. The ovaries were found to have assumed different degrees of development according to the length of the interval separating the time of capture and death, and it appeared as if the process of digestion must continue for at least two days after engorgement before the ovarian eggs became fully developed. None of the flies offered to oviposit on the moist walls of the bottles. In the open, during the period of post-engorgement, whilst digestion is proceeding, the females often congregate on the wire-screening of verandahs on houses near the river and also on the foliage of shrubs.

5. *Post-engorged individuals with blood-meal completely digested.*—An examination of the stomach-contents of these individuals collected at rest around houses and on shrubs, as well as on stones at the river, showed only a small mass of blackened, corpuscular debris, the elements of which could not be recognized. In all cases the ovaries were fully developed, each one containing at least fifty mature eggs. In some cases a few immature eggs were also present, and it is just possible that these are matured following a subsequent feeding. From the evidence at hand I was unable to ascertain definitely whether *S. simile* undertakes the act of oviposition more than once, or whether the longevity of the females is such that they may become engorged more than once. The simultaneous occurrence of mature and immature eggs in the ovaries of individuals, that have completely digested a blood-meal, is, however, significant.

As the eggs develop in the ovary, they undergo a decided change of shape as well as increase of size. The ovaries of unfed individuals consist of closely-aggregated.

small, rounded ova with a very delicate, vitelline envelope. The fully-developed ovarian ovum is, on the other hand, elongated oval in shape and provided with a comparatively thin, but tough, transparent shell.

Natural Enemies

S. simile proved to be the most abundant and important animal in the life of the rapids, with its extensive colonies of larvæ and clustered pupæ covering the stones over considerable areas. Invariably associated with it were the nymphs of a few species of may-flies, of which *Heptagenia* sp. appeared to be predominant. It was found that these nymphs fed extensively on *S. simile* larvæ and, therefore, play an important rôle in reducing their numbers. A few species of stone-fly and dragon-fly nymphs, which proved to be abundant in some localities, also greedily devoured the unprotected and unresisting larvæ.

In the Saskatchewan rivers there occur three species of fish, that are frequently taken on anglers' lines. Of these there are two, the common sucker, *Catastomus commersonii,* and the flat-headed chub, *Platygobio gracilis,* that have practically no food value and are commonly returned to the water when captured. The third is the western goldeye, *Hyodon chrysopsis,* which is extensively used as human food during the summer months. During July and August, 1921, an analysis of the stomach-contents of several specimens of each of these three species was made with the result that neither eggs, larvæ or pupæ of *S. simile* were found to constitute any part of the food of either chub or goldeye. In the case of the sucker, it was found that the stomach and intestine of all specimens dissected, contained the partly digested carcases of the larvæ and pupæ of *S. simile.* With one exception, in which ephemerid nymphs were numerous, the contents of the alimentary canal appeared to consist of nothing else but *simile* larvæ and pupæ, of which the larvæ were much more abundant. The fish were simply gorged with them. There can be little doubt but that suckers are responsible for the destruction of vast numbers of black-fly larvæ and pupæ each year, and their ventrally-situated, circular form of mouth with its fleshy lips appears to be admirably adapted for browsing on larvæ of *S. simile* in the rapids. As a natural factor of control, the sucker is much more important than any other predatory species, and the fact of its being unsuitable for human food renders the reduction of its numbers at present a remote contingency.

As regards the internal parasites of *Simulium* larvæ, Strickland* has given an interesting account of the infection of *S. bracteatum, S. vittatum* and *S. hirtipes* by three new species of Microspordia of the genus *Glugea* in the vicinity of Boston, Mass. Among some colonies he found that the proportion of parasitised individuals ran as high as 80 per cent, and that these micro-organisms proved fatal to their hosts. Parasitised individuals are readily observed in a colony by reason of their pathologically distended and pale abdomens, and whilst these same or closely-allied Microsporidia are apparently present in a small percentage of the larvæ of *S. bracteatum* and *S. vittatum* in the vicinity of Saskatoon, I have not observed them in the specimens of *simile* larvæ, which I have examined. Strickland observes that the numbers of adult black flies around Boston are comparatively small, although the larvæ are abundant in the streams, and he, therefore, concludes that the fatal effects of glugeid parasitism is effective in keeping them under control. No such agent would seem to be at work amongst *simile* larvæ in Saskatchewan, the numbers of which are apparently affected adversely only by an abrupt fall of the water-level or by an increase in the numbers of their predatory enemies. In addition to Microsporidia, Strickland records a gregarine species as a destructive parasite of *S. bracteatum,* as well as a species of the nematode genus *Mermis.* Other authors including Pomeroy and Edwards (*loc. cit.*) have recorded the occurrence of one or all of these parasites, the former of whom has also discovered the nematode in adult females of *S. venustum* and *S. bracteatum.*

* Strickland, E. H.—"Further Observations on the Parasites of Simulium Larvæ." Jour. Morph., vol. XXIV, No. 1, 1913.

Control of S. simile

Artificial Control.—The method of oiling rivers and streams for the destruction of simuliid larvæ is now well-known, as a result of the experiments of several authors, including Weed*, Conradit†, Sanderson‡ and Reeves§, carried on in the streams of the Adirondack Mountains, N.Y., White Mountains, N.H., and in Michigan. In some parts of the American continent the application of oil is now considered to be a satisfactory remedy and has been adopted quite extensively.

A requisite attribute of the oil is that it should be miscible with the water in all proportions. Several tests of the efficacy of phinotas oil as a larvicide were made in the river at Saskatoon and in a small tributary stream 5 miles north of the town. In the river-experiments, the oil was slowly poured into the water at a point about 20 feet above the location of a breeding-ground, where the larvæ of *simile* were present in inordinate numbers, and was so trained that the emulsified water passed directly over it. Observation showed that, when the oil came into contact with the larvæ, they almost immediately assumed an erect position and appeared uneasy. After about thirty-minutes, the larvæ commenced to surrender their footing on the rock-surfaces and were washed downstream. A large number appeared to recover completely from the baneful effects of the initial application of oil, but these were gradually overcome by subsequent applications. So far as the river is concerned, I am of the opinion that the extensive areas of the breeding-grounds and their occurrence at varying intervals would render the oiling method an expensive item. When one considers, also, that the bed of the river measures in places about 1,200 feet from shore to shore, it will be readily understood that a very large quantity of oil would soon become so diluted as to prove ineffective as a larvicide. The confinement of the oil in restricted channels, so as to ensure the maximum effects at the rapids, is also difficult of accomplishment, and it is carried by the current to reaches of water, where no larvæ are present, and thus wasted.

In the small tributary stream frequented by the larvæ of S. *bracteatum*, *S. venustum* and *S. vittatum*, the oil proved a more reliable larvicide than in the river. This stream has a very narrow but comparatively deep channel measuring not more than three feet across at its widest. From our tests we concluded that the application of about two gallons of the oil at a point about 250 yards from its mouth, would serve to destroy practically all the larvæ occurring on either stones or leaves of aquatic plants as far as its debouchement into the river. That the larvæ were killed by the oil and not merely washed down-stream,was ascertained by the use of strainers made of wire-netting, the mesh of which was sufficiently fine to prevent the passage of the larvæ. These strainers were fixed in position in the bed of the stream at places immediately below the location of colonies of the larvæ. After the application of the oil had been completed, the larvæ were found dead in the strainers. In some cases the effect of the oil seemed to be fatal almost immediately on its coming into contact with the larvæ. Aquatic beetles and fresh-water worms in the stream were also killed in large numbers.

Some authors have recommended the removal of the most-heavily infested stones in order to abate the black-fly nuisance. This method, I am convinced, would be much too arduous in the case of *S. simile*, when it is understood that practically every stone in such a barrier as is represented in figure 8, A, may be coated with the larvæ at certain favourable times during the summer.

Repellents.—In order to protect their livestock the farmers of Saskatchewan burn smoky, ill-ventilated fires known as "smudges" (fig. 9, B), or spray their animals with oily preparations. A "smudge" is most effective where it smoulders slowly and

* Weed, C. M.—"Experiments in destroying Black Flies." U.S. Dept. Agric., Div. Ent., Bull. 46, pp. 108-109, 1904.

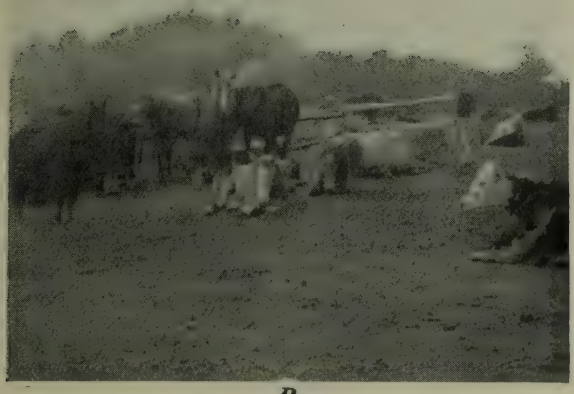
† Conradi, A. F.—U.S. Dept. Agric., Div. Ent., Bull. 52, 1905.

‡ Sanderson, E. D.—"Controlling the Black Fly in the White Mountains." Jour. Econ. Ent., vol. III, No. 1, pp. 27-29, 1910.

§ Reeves, C. D.—"A Remedy for the Black-Fly Pest in certain Streams of the Southern Peninsula of Michigan." 12th Rpt. Mich. Acad. Sci., pp. 77-78, 1910.

gives off a dense smoke. Grazing cattle and horses will readily congregate around one of these "smudges" and they, apparently, are quite ready to appreciate the ability of the smoke to ward off the flies. When the fire burns out, the animals will often be found resting among the dead embers (fig. 9, A). For animals that must be worked

A.



B.

Fig. 9.—A, cattle resting on the site of a burnt-out "smudge," attacked by a swarm of *Simulium simile;* B, cattle and horses congregated around a "smudge," the smoke of which offers protection against the attacks of *Simulium simile.* (Original).

during the day, protection is secured by the application of a repellent consisting of an emulsified oil, made as follows: two gallons kerosene, half a pound soft soap, one gallon soft water. The soap is dissolved, and the resulting solution added to the kerosene, the whole being thoroughly stirred. The addition of one part of this mixture

to five parts of water furnishes the requisite repellent effect, when applied as a fine spray on the coats of the animals by means of a knapsack spraying-machine. An alternative mixture, as devised by the Kansas Experiment Station, in Press Bulletin No. 65, consists of the following ingredients: resin (pulverised) 2 parts; soap shavings, 1 part; water, ½ part; fish oil, 1 part; oil-of-tar, 1 part; kerosene, 1 part; water, 3 parts. The resin, soap, fish oil and half part water are boiled together until the solution of the resin is completed. The three parts of water, kerosene and oil-of-tar are then added and the whole mixture thoroughly stirred and boiled for fifteen minutes. Before being used as a spray, the mixture is allowed to cool. Either one of the above repellents has proved satisfactory, the only objection being that the applications must be repeated at least once or twice every day, as their offensive qualities are often quickly lost. Further, the oily mixtures prove themselves excellent media for the adherence of dust, so that the animals soon present a dirty condition, which is not readily remedied.

Other Species of Simuliidae Prevalent in Saskatcheman

None of the other species of *Simulium* studied in Saskatchewan, have so far proved very troublesome to live-stock or to human beings, although the adult females of *S. venustum, S. vittatum,* and *Simulium* sp. undet, have frequently been taken attacking cattle and horses. Next to *S. simile, S. vittatum* seems to be most abundant, but, numerically, it is entirely overshadowed by the former. The adults are on the wing from June to October, and the females are frequently taken engorging upon cattle. Like the females of *S. simile,* they often enter cow-barns attached to their hosts, but they almost immediately cease feeding when the cattle are under cover. They are attracted by the light and, along with *simile,* they are found on the glass of the barn-windows. *S. venustum* has been taken occasionally on horses, and the undetermined species of *Simulium* viciously bites cattle. Another species, *S. bracteatum,* although quite common, has not been so far incriminated as a blood-sucking insect here. *S. bracteatum, S. venustum, S, vittatum* all pass their early stages attached to either stones or water-weeds in small streams and never occur in the larger rivers. Larvæ and pupæ of all three species occur from the beginning of June to the end of September, and larvæ and pupæ of *S. vittatum* have been taken in a small stream under ice as late as the middle of October. It is more than probable that the yellow, undetermined species will be found to be a river inhabitant, sharing the habitat of *S. simile* in its early stages. In this respect it is significant that the adults have been reared on three several occasions in the tanks, in which *S. simile* was being bred from larvæ taken from the river. Its numbers are entirely overshadowed by those of *S. simile,* which partly explains our failure to detect its larvæ among those of the more abundant species. During August and September, the adults, both male and female, have been frequently captured on the wire-screened walls of the insectary on the campus of the University of Saskatchewan. Engorged females were taken on a horse at Saskatoon on August 6, 1918, and also frequently on cattle. That the blood-sucking habit is not rare may be judged from the frequency with which the engorged females were found on the windows of the stables and cow-barns at the University farm, to which they had escaped on the abandonment of their hosts.

SUMMARY.

Simulium simile is a species of black fly that, in Saskatchewan, passes its pre-adult stages in the stony rapids of the North and South Saskatchewan rivers. The adult female was described by J. R. Malloch, in 1919, from specimens collected in 1915 by R. M. Anderson, at Hood river, Arctic sound and Bathurst inlet, Northwest Territories. The egg, larva, pupa and male are described and illustrated for the first time in this bulletin from material collected in the South Saskatchewan river at Fish Creek and Saskatoon.

The eggs are deposited in masses, embedded in a soft, gelatinous matrix on the stones of the rapids near the water-line, where they are kept moist by the spray. The larvæ, which feed chiefly on diatoms, form large colonies on the stones, changing, when fully developed, to pupæ enclosed in shoe-shaped, coarsely-woven, silken cocoons, that sometimes form coral-like encrustations, where they are particularly numerous and closely aggregated. There are probably four broods per annum in central Saskatchewan, the larvæ and pupæ occurring from June to October. They are most numerous during the early part of the summer when the water is high, their numbers diminishing as the summer proceeds owing to the reduction in the extent of the breeding-grounds caused by the recession of the water. The mortality amongst the larvæ and pupæ due to dessication arising from the periodic fall of the water-level, is at times very great and may furnish a partial explanation of the variation in the numbers of the adults from year to year.

The stage of hibernation is not known. The delicate eggs covered by a thin, tough shell and protected by the soft, adhesive jelly do not readily appeal to one as being suitable to withstand either dessication or zero temperatures. Nevertheless, the first-stage larvæ are the first to appear in the summer about five or six weeks after the ice disappears. Similarly, these young larvæ are found on water-washed stones, that are exposed intermittently throughout the summer when the water falls, a fact which would suggest the possibility of latent periods, during which the eggs may retain their vitality for longer or shorter intervals, although deprived of moisture.

The emergence of the adults, the sexes of which occur in about equal proportions, takes place in great swarms, particularly on the occasion of the appearance of the large initial brood. If the prevailing weather-conditions are favourable, the adults are carried before the wind for long distances away from the breeding-grounds, so that their presence in localities 10 or 12 miles from the river is a common occurrence. The mortality among the emerging adults as a result of drowning is often very large. A wide strip several hundred yards in length consisting of their dead bodies, has been observed adjacent to the site of one breeding-ground, where the water lapped the shore.

The adult female is tenaciously parasitic on cattle and horses. By reason of its persistent blood-sucking habit, it is responsible for sapping the vitality of its hosts. In feeding, the female generally selects the forequarters, under-surface of the belly and inguinal region. They may literally plaster their hosts. In certain districts they have been suspected of causing the death of cattle, horses and mules. Proof of the ultimate cause of death in the host has not been forthcoming, whether it be (1) a pernicious constitutional wasting consequent on systemic debility due to the continued loss of blood from innumerable, œdematous punctures (2) suffocation due to the inhalation of the swarming insects and mechanical obstruction of the bronchi (3) the injection of some toxic substance, a product of the activity of the salivary glands, or (4) the presence of a pathogenic micro-organism, of which *S. simile* may be the vector. To the author any one of the first three suggested causes appear plausible and possible, but investigation of the probable transmission of a pathogenic micro-organism yielded results of an entirely negative character.

As is the case with many other blood-sucking insects, the development of the ovaries of *S. simile* would appear to be determined by two contingencies, namely (1) the ingestion of a blood-meal and (2) the degree of digestion of the meal. At least two days must intervene between the condition of full engorgement and the "complete" development of the ovaries. Even so, there is a residuum of undeveloped eggs in some individuals, the presence of which might pre-suppose their maturing at a subsequent date, should the female live long enough to become engorged a second time. As to whether *S. simile* may become engorged and oviposit more than once is not readily determined, as the female does not prove amenable to experimentation under conditions of captivity.

Man is not a host of *S. simile*. On occasion, it may cause mild annoyance to human beings by persistently flying around their heads. It has never been observed to settle with intent to bite, but, under certain conditions, both males and females may alight on an observer's clothes. The adults of both sexes will readily seek shelter on inclement days on the wire-screening of verandahs and amongst the foliage of shrubs.

Among the natural enemies of the larvæ, the voracious nymphs of may-flies and stone-flies, which also inhabit the rapids, are important. A species of fish, known as the sucker (*Catastomus commersonii*) because of the suctorial form of its mouth, is the principal enemy of the larvæ and pupæ. It is proving itself one of the most successful agents of natural control. Dissection has shown that this species mainly subsists during the summer on the larvæ and pupæ, which, in some specimens, completely fill the stomach and intestine. No indication of sporozoan parasitism of the larvæ of *S. simile* was found, although other species of black-fly larvæ were found to be infested in small degree.

As a result of the experimental tests with miscible (phinotas) oil, it was shown that the larvæ could be killed. The experiments, however, did not prove to be quite so satisfactory with the larvæ of *S. simile* in the river as with those of *S. bracteatum, S. venustum* and *S. vittatum* in a small stream. A comparison of the different conditions attendant on the habitat of the river and stream larvæ might explain the difference in the efficacy of the oil, chief amongst which is the consideration of the more rapid dilution and consequent reduction in the strength of the larvicide in the river owing to the greater bulk of the diluent. Added to this is the difficulty of strictly confining the larvicide to the various breeding-grounds in the river, so that there is an appreciable wastage owing to spreading.

A certain amount of protection against the attacks of the females is secured for grazing cattle and horses from the smoke of "smudges," consisting of ill-ventilated, smouldering fires made of any kind of rubbish. The animals may also be temporarily protected by being sprayed with oily preparations, which are renewed from time to time as their repellant effect decreases.

Of the other species known to the author in the province, all are small-stream species with the exception of one as yet undetermined and probably new. It perhaps shares the same habitat as *S. simile* in the rivers. Like *S. simile,* the adult females of the remaining species, including *S. venustum* and *S. vittatum,* are blood-sucking. *S. bracteatum* has not so far been incriminated in this habit.

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Insects and Their Control, Common Garden	"			No. 9
Tussock Moth, The Habits and Control of the White Marked	"			No. 11
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